



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

**STRATEGY TO ACHIEVE ENERGY AND WATER  
SUSTAINABILITY IN LATIN AMERICA THROUGH  
HUMANITARIAN ASSISTANCE AND DISASTER  
RELIEF OPERATIONS**

by

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**STRATEGY TO ACHIEVE ENERGY AND WATER SUSTAINABILITY IN LATIN  
AMERICA THROUGH HUMANITARIAN ASSISTANCE AND DISASTER  
RELIEF OPERATIONS**

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## **ABSTRACT**

The United States is a leader in humanitarian assistance and disaster relief, and the Department of Defense is called upon by Department of Defense Directive 5105.65 to lead efforts to assist nations in need of education support, health support, disaster preparedness, and basic infrastructure. Latin America is a strategic neighbor of the United States and is susceptible to man-made and natural disasters. Many of the countries that make up Latin America lack access to clean water, proper sanitation, and sources of electricity. The purpose of this thesis is to explore the capabilities of a technology that provides sanitation and water treatment services, the byproduct of this technology is drinkable water, electric power, and construction-grade ash, and then relay this technology to a humanitarian assistance and disaster relief role in Latin America. This thesis also discusses the rule of law index, influence on host nation governments, population makeup, and area characteristics to consider when determining whether to proceed with a humanitarian assistance or disaster relief project that incorporates water-sanitation-power combined technology.

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## LIST OF ACRONYMS AND ABBREVIATIONS

CCMDs	Combatant Commands
CRF	Coastal Riverine Force
DOD	Department of Defense
DSCA	Defense Security Cooperation Agency
DR	Disaster Relief
ECRC	Expeditionary Combat Readiness Command
EOD	Explosive Ordnance Disposal
EXWDC	Expeditionary Warfighting Development Center
HA	Humanitarian Assistance
HN	Host Nation
kW	Kilowatts
kWh	Kilowatt-hours
LAC	Latin America and Caribbean
MCAST	Maritime Civil Affairs and Security Training Command
ml	Milliliters
MW	Megawatts
NAVELSG	Navy Expeditionary Logistics Support Group
NECC	Navy Expeditionary Combat Command
NEIC	Navy Expeditionary Intelligence Command
NGWA	National Groundwater Association
O&M	Operations and Maintenance
OHASIS	Overseas Humanitarian Assistance Shared Information System
Seabees	Naval Construction Force
SC	Security Cooperation
U.S.	United States
USAID	United States Agency for International Development
WHO	World Health Organization

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## **I. INTRODUCTION**

### **A. HUMANITARIAN ASSISTANCE PROGRAM**

The Defense Security Cooperation Agency (DSCA) manages the humanitarian assistance (HA) program. It is a program that builds on the partner nation's capacity to provide essential services to civilian populations through civil–military engagement (Defense Security Cooperation Agency [DSCA], 2016). The HA program's primary function is to alleviate the aftermath of “natural or manmade disasters or other endemic conditions such as human pain, disease, hunger, or privation that might present a serious threat to life or that can result in great damage and loss of property” (DSCA, 2016, p. 12.5.1). HA is a tool used for security cooperation (SC) in an effort that can “improve visibility, access and influence as well as promote regional stability with foreign military and civilian counterparts” (DSCA, 2016, p. 12.5.3).

### **B. THE DEPARTMENT OF DEFENSE ROLE IN HA**

The Department of Defense (DOD) has a long history of HA because it “can contribute unique and vital capabilities and resources as it possesses the manpower, material, and organizational assets to respond” (Serafino, Dale, Grimmett, Margesson, Rollins, Salaam-Blyther, Tarnoff, Woolf, Wyler, & Bowman, 2008) to humanitarian and disaster relief (DR) situations. The DOD's response in the 2010 earthquake in Haiti, Operation Unified Response, is an example of a DR situation, and most DR operations operate the same way. Operation Unified Response was divided into five phases and each had a specific purpose and expectation of response (see Table 1) (Cecchine, Morgan, Wermuth, Jackson, Schaefer, & Stafford 2013).

Table 1. Phases of Operation Unified Response

Phase	Actions	End of Phase
I—Initial Response	Immediate lifesaving actions, situational assessment and crisis action planning	Forces are deployed or employed to mitigate near-term human suffering
II—Relief	Forces provide immediate disaster relief to assist the affected population	When immediate humanitarian needs have been met (water, food, shelter, sanitation, medicine etc.)
III—Restoration	Reconstruction of key infrastructure (roads, power, communication)	When the infrastructure in affected areas is rehabilitated to a state where government agencies can assume roles in long-term recovery
IV—Stabilization	Required when there is no functioning, legitimate civil governing entity present	When legitimate local entities are functioning
V—Recovery	Support to legitimate civil governance in order to enable civil authority	When civil authorities have the capability and capacity to effectively provide HA/DR to their population without U.S. assistance

Adapted from Cecchine et al., 2013.

HA activities within the DOD are divided across four sections in the Overseas Humanitarian Assistance Shared Information System (OHASIS): education support, health support, disaster preparedness, and basic infrastructure (DSCA, 2016). OHASIS organizes and analyzes projects among the four sections, allowing project comparisons across countries, regions, and Combatant Commands (CCMDs).

## 1. Education Support

The DSCA's educational support activities strive to build the foundation for "continuous learning and development while promoting an understanding of basic human rights" (DSCA, 2016). The objective of education support is to empower communities by removing information dependence and influence from extremist groups and other radicalized individuals. They provide the tools necessary for self-reliance when external support and resources are limited. Examples include

constructing schools, rehabilitating orphanages, and creating projects that supply school furniture and other educational materials (DSCA, 2016).

## **2. Health Support**

Health support activities are projects designed to mitigate disease and improve the standard of care within a population. These projects emphasize basic survival needs and preventative methods that build on the capabilities of the host nation (HN) (DSCA, 2016). This allows the government of the HN to have more influence over its citizens and lessens the impact of outside extremists. Projects are coordinated with the United States Agency for International Development (USAID) to include public health surveys, assessments, and medical support, and capacity building of supplies (DSCA, 2016).

## **3. Disaster Preparedness**

The DSCA's disaster preparedness projects also build on the HN's capability with an effort to meet the humanitarian needs of the civilian population (DSCA, 2016). In addition, these projects provide a way to engage with multiple stakeholders in a neutral environment that establishes a method to strengthen relationships. Examples include constructing or repairing emergency operations centers and disaster relief warehouses, as well as emergency response training (DSCA, 2016).

## **4. Basic Infrastructure**

Basic infrastructure projects meet the needs essential for human survival, allowing for long-term stability. Projects can develop a new or enhance an existing HN capability in a way that allows the HN to maintain and sustain the finished project (DSCA, 2016). Examples include construction and repair of rudimentary surface transportation systems, public facilities, sanitation and distribution of water supply, well drilling, and repair of electrical production and distribution systems (DSCA, 2016).

## **C. NAVY EXPEDITIONARY COMBAT COMMAND**

The Navy Expeditionary Combat Command (NECC) is a Navy Echelon III command that is the central manager for the Navy's expeditionary forces. NECC makes sure its Echelon IV subordinate commands are properly resourced and ready for deployment. The Echelon IV commands are Coastal Riverine Force, Naval Construction Force (Seabees), Explosive Ordnance Disposal, Navy Expeditionary Logistics Support Group, Navy Expeditionary Intelligence Command, Expeditionary Combat Readiness Command, and Expeditionary Warfighting Development Center (United States, 2016b). The NECC's Echelon IV commands are the tactical driver for a variety of missions that include: waterborne and ashore anti-terrorism, force protection, theater security cooperation and engagement, HA/DR contingencies, and supplementing other governmental agencies for homeland security (United States Navy, 2016b).

### **1. Navy Construction Force**

"The Seabees are technical experts in engineering and have a wide range of construction capabilities that include: building roads, bridges, bunkers, airfields, and logistics bases" (United States Navy, 2016a). Since World War II, the Seabees have played a role supporting kinetic military engagements to major HA/DR operations. The Seabees have supported military conflicts such as the Battle of Guadalcanal and the force protection of Henderson Field (Philippart, 2004). They were called upon to assist with HA/DR operations resulting from the 2005 Hurricane Katrina, 2010 Haiti earthquake, 2011 Japan tsunami, and others. They are a vital element in the support of military engagements and HA/DR operations, and "perform civic action projects to improve relations with other nations" (United States Navy, 2016a).

### **2. Military–Civil Affairs**

From 2009 to 2014, NECC had an Echelon IV subordinate command, Maritime Civil Affairs and Security Training Command (MCAST), that engaged in relationship enhancements between military forces, foreign governments, and

civilian populations (Daniels, 2014). MCAST formed teams composed of five to eight personnel trained in civic relations, civilian medical capability assessment, security, and city planning, and the teams would interact with the local population to identify areas that could improve the relationship between civilians and the military (Civil, 2015). Although MCAST was disestablished, the United States Army still maintains their civil affairs program. Army civil affairs specialists “help plan government interagency procedures for national or regional emergencies and assist with civil–military planning and support; coordinate military resources to support reconstruction activities in support of HA/DR operations and maintain dialogue with civilian aid agencies and relief organizations” (United States Army, 2016). Civil affairs teams are instrumental in identifying projects like well-drilling, building schools, building bridges, and others that will improve United States relationships with other nations by winning the hearts and minds of the local population and forming alliances with foreign governments.

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## **II. WATER AND SANITATION CHALLENGES IN LATIN AMERICA**

### **A. ACCESS**

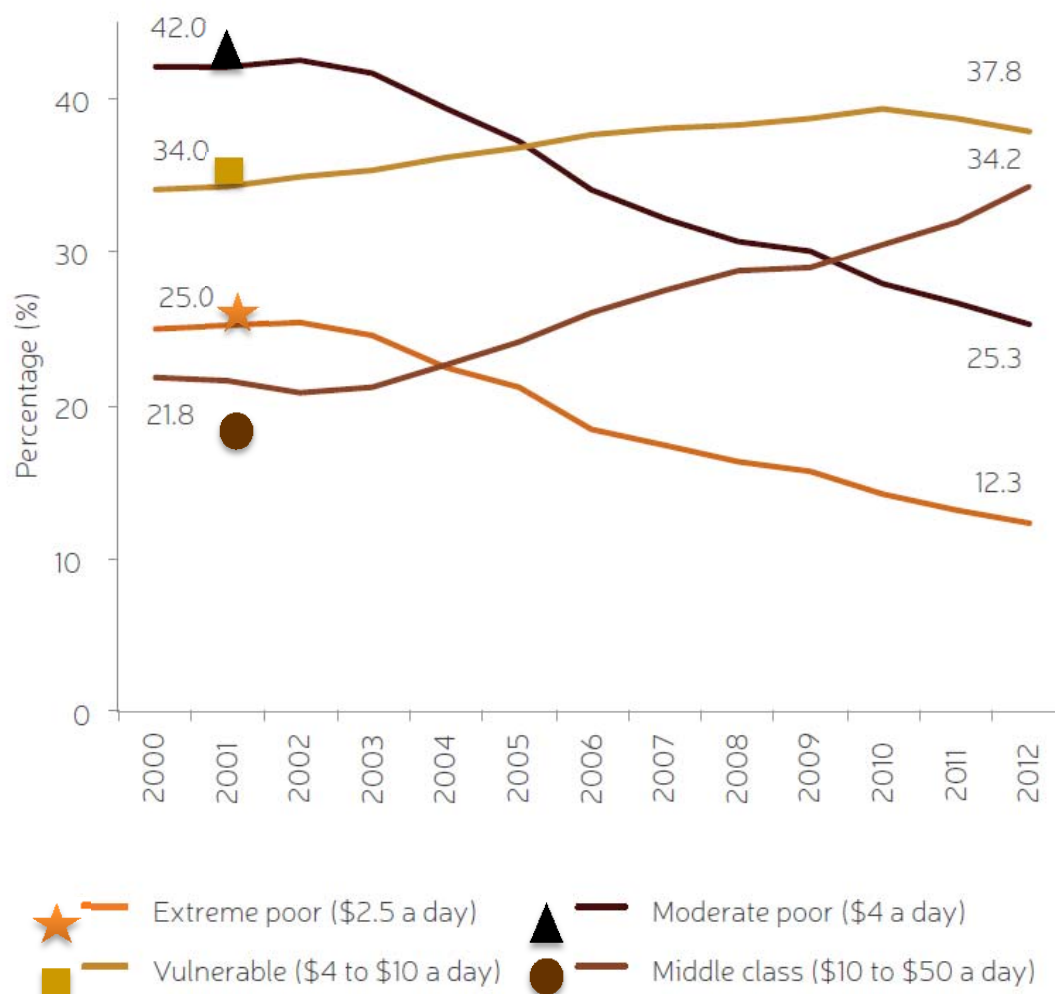
Latin America spans Mexico to the southern tip of Chile (see Figure 1). It is the most water-rich region in the world, containing 31% of the world's freshwater resources (The World Bank Group, 2012). A study conducted in 2014 found that most Latin American countries are not developed enough nor have the infrastructure capable to treat and transport fresh water that is safe for human consumption (Perez, Basz, & Azevedo, 2014). Perez, Basz, and Azevedo also found that one of the causes that contribute to this is the general public's lack of understanding of the need for clean water as they do not fully understand the health risks associated with unclean water. Also, most people do not understand the true monetary costs of what it takes to build treatment plants, lay transport pipes, and provide plumbing to their homes. There is unwillingness among the general population to provide funds for that infrastructure, either by collecting taxes or fees, because they believe that water should be free (2014). In their 2014 study, the World Bank (as cited in Perez, Basz, & Azevedo) found that 25% of the population made less than \$4 per day, 38% made between \$4 and \$10 per day, and 34% made \$10 to \$50 per day (2014; see Figure 2). This level of poverty renders any fund collection futile. The majority of the money that is collected and set aside for water projects is used primarily for city development. Approximately 80% of Latin Americans live in urban environments and the demand for water in these areas continues to grow as more people flock to cities in an effort to find jobs (Perez, Basz, & Azevedo, 2014). The struggle to meet the demand of urban areas leaves those in rural areas with little to no clean water access.

Figure 1. Map of Latin America



Source: Wikipedia, 2016.

Figure 2. Poverty, Vulnerability, and the Middle Class in Latin America and the Caribbean (2000–2012)



Source: Vakis, Rigolini, and Lucchetti, 2015.

## **B. CONTROL AND WATER RIGHTS ISSUES**

The World Water Council is an international multi-stakeholder platform whose mission is to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient conservation, protection, development, planning, management and use of water in all its dimensions on an environmentally sustainable basis for the benefit of all life on earth.

—World Water Council, 2015

The World Water Council operates as an umbrella organization that restricts itself to policy related issues and assumes a facilitator role for cross-cutting programs. It receives financial resources through fees from members and licensing. Donations and grants from governments, international organizations and donors provide funding for specific projects and programs (World Water Council, 2015).

Every three years, the World Water Council hosts a World Water Forum. In 2006, the fourth World Water Forum was held in Mexico City, Mexico. There they discussed the challenges of Latin America with regard to water and sanitation. It was reported that “77 million people lack access to safe drinking water and 100 million lack access to sanitation services” (World Water Council, 2006).

Regardless of its recognition of a lack of clean water and sanitation services, the World Water Council is criticized for its influence on privatizing and commercialization of water sources and sanitation service facilities. Critics argue that corporations are close to monopolizing water in Latin America and it has led to high prices and low quality (Boscov-Ellen, 2009). Bolivia is used as an example in which water privatization and commercialization was devastating. In 1997, corporate control of water rights was given to Aguas de Tunari and Aguas de Illimani. After taking control, both companies raised water rates. The average water rate increased by slightly over a third with some locations going up by two times the previous rate (Boscov-Ellen, 2009). “Licenses were even required for individuals to collect rainwater from their roofs, and people were charged for

water taken from their own wells” (Boscov-Ellen, 2009). The people protested vigorously to the point that martial law was declared. Eventually, both companies were driven out of the country and operations ceased. Even though the two companies were driven out, some still recognized that the fight over water rights remained prevalent. The Latin American coordinator of Food and Water Watch’s Water for All Campaign stated:

the other battle that’s still going on, that we’re fighting now in the form of the struggle over water rights, has to do with our not being able to put together an effective, participatory popular alternative with social controls to serve as a counter to privatization, to private control of resources. This is a battle that’s still being waged in Cochabamba, but it’s less romantic and not so easy to talk about, because there are a lot of problems with the water company. Things have not been resolved now that the company has been reclaimed. I think this is where the true work lies—work that is harder, unrecognized, and still involves an entrenched battle. (Boscov-Ellen, 2009)

Proponents for water privatization argue that Latin American governments are not able to provide water and sanitation services because of incompetence, corruption, or overextension. They believe that the open market is the best method to efficiently manage sanitation services and water as a resource. The notion is that people will not waste water if they have to pay for it (Boscov-Ellen, 2009). As in Bolivia’s case, when Aguas de Tunari and Aguas de Illimani were forced to cease operations, Bolivia’s municipal water service had to take over the responsibility. They lacked the capability to service all citizens and outlying districts went without water. In spite of the Bolivian government including water as a constitutional right and banning funding toward private companies, they still struggle with the task of funding and implementing projects designed for water treatment and distribution.

### **C. HUMAN AND NATURAL INFLUENCES ON WATER AND PEOPLE**

Aquifers represent a major source of fresh water in Latin America. Forty to 60% of the water that comes from these sources faces significant pollution from

mining and agricultural operations (World Water Council, 2006). In addition, population growth is causing overuse. In Mexico, 102 of the 653 aquifers that supplies 65% of the population are overused (World Water Council, 2006). Many farmers are forced to switch to less profitable crops, like grain, as it requires less water to grow than more lucrative crops, like cotton, as cotton requires more water than the aquifers can produce. Like aquifers, rivers and lakes are heavily impacted by pollution from industrial run-off and overexploitation from rapid population growth (World Water Council, 2006).

Garbage disposal is an overwhelming problem throughout Latin America. Although some cities have developed better waste management facilities, the majority of Latin America utilizes open dumps as a means to dispose of trash. Approximately 400,000 tons of solid waste is generated per day in Latin America (Marello & Helwege, 2014). The disposed waste seeps into rivers, streams, ponds, and lakes polluting these water sources used by the surrounding population. Citizens also use the dumps as a means of survival. They search and dig, by hand, through the garbage to find any reusable material that they can keep or sell which exposes them to a plethora of toxic gases, harmful bacteria, and other pathogens that thrive in that environment (Watts, 2015).

The Latin American region is highly susceptible to natural disasters (see Figure 3). It experienced an average of “8.3 disasters per year from 1900 to 1989 and 40.7 from 1990 to 1998” (World Water Forum, 2006 p. 7). The World Bank Regional Director for Sustainable Development, Ede Ijjasz-Vasques, stated: “The poorest are most affected by droughts and floods, they are the least able to organize themselves against such occurrences, and have little access to financial tools, such as savings and insurance” (The World Bank Group, 2013). Natural disasters such as floods, earthquakes, tidal waves, and landslides increase the probability of fresh water contamination from landfills and ocean water. They can further reduce access to safe drinking water by destroying the surrounding infrastructure. This increases the health risk to the population because of a

further reduction in sanitation services and the residual stagnant polluted water is a breeding ground for disease carrying mosquitoes.

Figure 3. Natural Disasters by Country, With Population Density, From 1900–2007



Source: Maynard-Ford, Phillips, and Chirico, 2008.

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### **III. GREEN TECHNOLOGY COMBINING SANITATION, WATER TREATMENT, AND ENERGY GENERATION**

#### **A. OVERVIEW**

There are multiple technology systems used by companies and governments around the world that treat water to make it safe for drinking, produce electricity, and provide a method of collecting, storing, and treating sewage; however, these technologies operate independently of each other. An alternative method to support HA/DR operations is to utilize green technology that combines sanitation, water treatment and electrical power services with minimal impact to the environment and the surrounding population. A prototype system that combines sanitation service, water treatment, and electrical power is the Janicki Bioenergy Omni Processor (OP). It is a water treatment and electrical power plant built by the Janicki Bioenergy Company that utilizes sewage sludge and other nontraditional sources of fuel to produce clean drinking water, electricity, and pathogen-free ash. It is not capable of processing metal, glass, batteries and other toxic materials.

For an OP that uses sewage sludge as fuel, the process begins when the sewage sludge enters the machine and proceeds through a dryer where it is boiled. During boiling process, water vapor is separated from the sewage sludge. The dry sludge is then fed into a fire furnace which creates high temperature, high pressure steam. The steam is captured and directed into a steam engine that drives a generator in order to create the electricity used for the OP. Excess electricity is transferred to the community. The water vapor captured in the boiling process is run through a cleaning system that produces high-quality drinking water. The ash is used to create building materials similar to cinder blocks (Janicki, 2016).

## **1. S100**

The S100 is the prototype OP built and tested in Sedro-Woolley, Washington. The machine footprint is 8 meters by 23 meters. It can produce 10,800 liters (2,853 gallons) of water from 12.3 cubic meters (3,249 gallons) of sewage sludge per day and has a maximum power output of 150 kilowatts (kW). The drinking water produced meets both United States Food and Drug Administration (FDA) and World Health Organization (WHO) standards (Janicki Bioenergy, 2016a).

After initial trials and tests, the S100 was deconstructed and transported to Dakar, Senegal, to use as a pilot program in February 2015. In Dakar, 1.2 million people do not have access to a sewer line (Mbequere, 2016). Instead, they utilize individualized pits in their homes. When the pits are full they are emptied either manually by shovels and buckets or mechanically via suction machinery. Manually removing the sewage sludge is done by digging a hole near the home and transferring it, bucket by bucket, to the hole. The laborer is in direct contact with the sewage and that poses a severe health risk to that individual. The hole leeches pathogens into the environment, contaminating water sources and the surrounding population. Mechanical removal is better as no human contact is made with the sewage sludge; however, the waste was previously dumped into rivers and streams. Prior to the S100, there was not a way to remove pathogens from the sewage sludge. The S100 treats one-third of the sewage sludge in Dakar (Gates, 2015).

## **2. S200**

The S200 OP is larger with greater capacities than the S100. The core footprint of the plant is 11.5 by 20 meters (38 by 66 feet). Additional options added increase the size to 11.5 by 29 meters (38 by 95 feet). The water purification unit takes up an additional 12 by 2.5 meters (39 by 8 feet). An overall area of 1200 square meters (1,435 square yards) is recommended for sufficient space for vehicles and operating space. It produces up to 86,000 liters (22,718

gallons) of water and 250kW of continuous electricity per day (Janicki Bioenergy, 2016b). It is designed to use additional means of fuel in addition to sewage sludge such as paper, plastic products, domestic house waste, bio-waste, and animal waste. It requires approximately 10–12 tons of dry waste per day as fuel. It can process fecal waste from approximately 100,000—200,000 people, 92.3 cubic meters (24,383 gallons) of wet fuel, with moisture content up to 100% as long as the 10–12 tons of dry fuel is supplied (Janicki Bioenergy, 2016b). Roughly 86,000 liters (22,718 gallons) of graywater and contaminated fresh water can be processed so long as the 10–12 tons of dry fuel is provided (Janicki Bioenergy, 2016b). The S200 is designed to operate independently from existing electrical grids; however, it can feed electricity it produces into existing infrastructure.

## **B. ECONOMIC IMPACT**

The OP has the potential to provide positive environmental, economic, and health benefits where it is used. After plant construction is completed, it only requires a couple of workers per shift to run operations; however, more jobs are created from the collection and sorting of fuel input and the selling and distribution of water, electricity, and ash output. In Dakar, Senegal the ash is converted into high quality construction material making sanitation a profitable business which attracts entrepreneurs from around Africa (Faye, 2016). Essentially, profitable business is created out of waste and this has influenced the perspective of sanitation as an industry.

## **C. COST AND LIFE CYCLE MANAGEMENT**

The S200 takes two to four weeks to build and has an expected lifespan of 20 years. It costs between \$2 million and \$4 million, depending on options chosen. Janicki Bioenergy is developing a series of like products with capability differences that range in cost between \$300,000 and \$7 million. Shipping costs are included in the price of the machine; however, shipping time varies and can only be determined once specific information is provided. Operations and

maintenance (O&M) costs range between \$750 and \$1,250 per day (Janicki Bioenergy, 2016b).

Janicki Bioenergy provides lifetime technical and maintenance support which covers the cost of O&M and guarantees technological performance. They provide 24 hours per day remote assistance and support and supplies spare parts and software upgrades as necessary. Live camera and data feeds allow plant engineers to monitor and troubleshoot remotely. Only onsite labor for daily operation and site improvements are not included (Janicki Bioenergy, 2016b).

#### **D. ALTERNATIVE METHODS**

There are many non-profit agencies that have the capability to assist with sanitation and clean water requirements. Some use varying levels of filtration methods however, the vast majority address these issues by drilling wells for clean water and simple education to address proper sanitation practices. For example: the National Groundwater Association (NGWA) lists 45 partner organizations world-wide that emphasize sanitation education in combination with well drilling with varying capability and water output (National Groundwater Association, 2015).

##### **1. Filtration**

A large scale filtration method is reverse osmosis. This is a process that removes contaminants by using pressure to force water through a semi-permeable membrane (Luthra, 2016). The major problem with this type of system on a large scale is the cost to build and the energy consumption it takes to maintain. The reverse osmosis plant in Carlsbad, California, costs \$1 billion to build with operating costs of \$49 million to \$59 million per year and energy consumption to operate the plan is estimated at 40 megawatts (MW) of power for continuous use (Phillips, 2013).

## **2. Well Drilling**

Drilling wells is a cheap and popular choice for fresh water access. Despite this, common issues exist. Groundwater contamination is a factor and the deeper the drill needs to go to avoid contaminated water, the more expensive the operation. In addition, the well location is contingent on the geological survey of where the best place to drill is. This can put a well miles away from the serving community. Although a drilling operation can be relatively inexpensive, a simple shallow well (150–200 feet) with a hand pump can average around \$7,000 in Africa and serve 2000 people; similarly in Latin America depending on the variables of the drilling operation, overuse remains a problem (Water Wells for Africa, 2016). Usage fees are often implemented to mitigate that issue.

## **3. Sanitation Education**

Sanitation education is a must but the majority is in the form of proper food handling and waste disposal. Although this education can include intensive training and motivation seminars, failure to adhere to proper hygiene and sanitation practices can make the health benefits of clean water wells useless. Although most bacteria and contaminants are filtered through soil, sand, or rock, well water is still at risk for contamination. Bacteria and sewage can seep through coarse soil, fractured bedrock or sinkholes. Improperly capped or sealed wells allow for disease-carrying insects and rodents to make their way into the well water source and if gone unnoticed the population is at risk for health illnesses. (Centers for Disease Control and Prevention, 2015). Well drilling does not solve the issue of sanitation.

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## **IV. LOCATION DECISION CRITERIA**

### **A. GOVERNMENT**

The United States holds a national security interest to ensure that Latin America maintains stable, secure, and prosperous democratic societies and partnerships with them help the United States support this interest (U.S. Department of State, 2016). Not all governments in Latin America are stable and corruption runs rampant throughout the region; therefore careful consideration should be taken into account when selecting a location for humanitarian partnership projects.

#### **1. Rule of Law Index**

The World Justice Project maintains the Rule of Law index that measures government performance with 44 indicators within eight themes (see Table 2). The Rule of Law index is a tool to use for identifying which countries have favorable governments by their people. This can help determine which country is best suited for a partnership humanitarian project. Even though intentions are pure, efforts could prove useless if the HN denies its citizens access to the benefits of humanitarian projects or impose unreasonable regulations on the use or distribution of those benefits. It lists Uruguay as the most favorable government (see Figure 4) and Venezuela the least favorable government (see Figure 5).

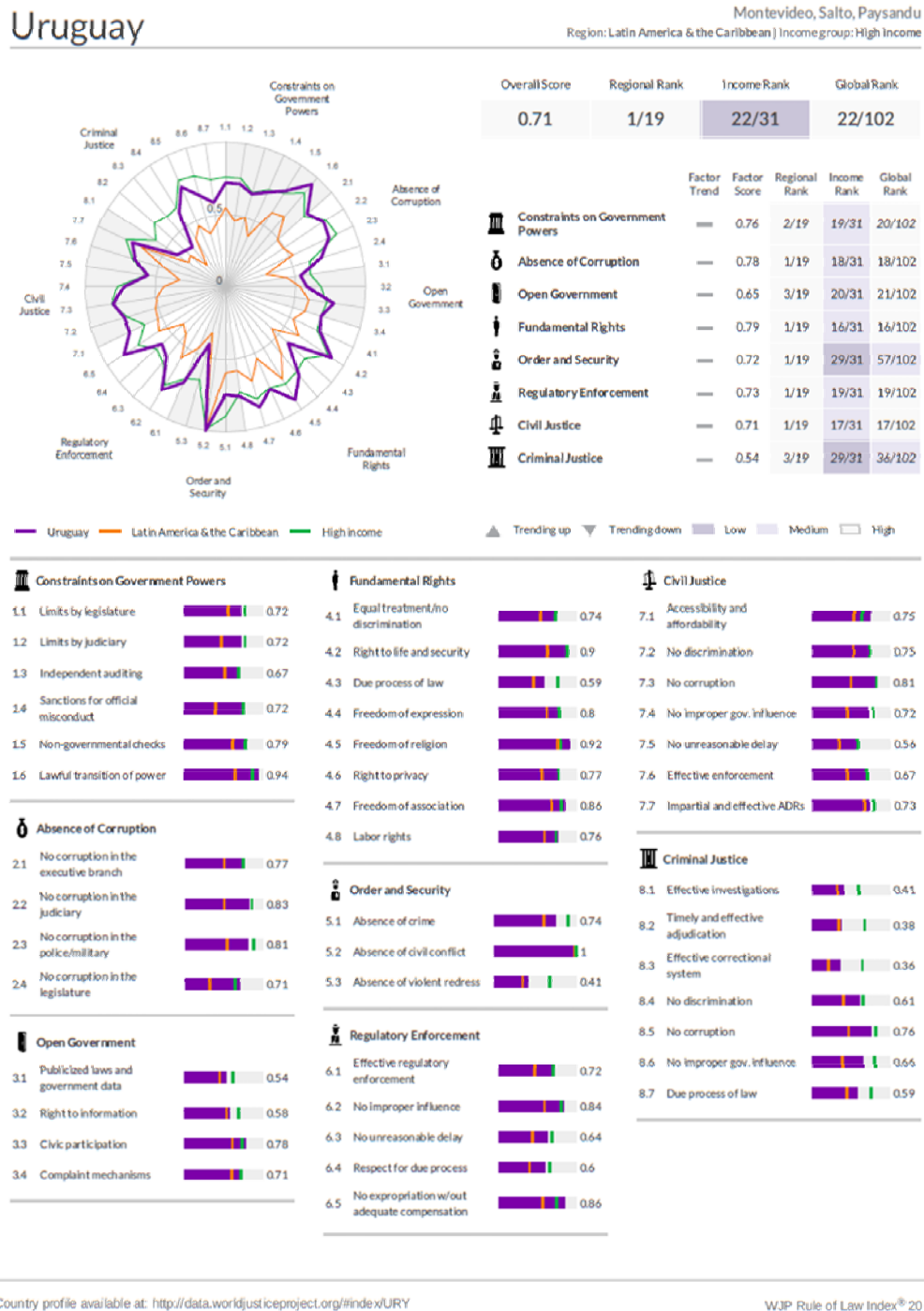
Table 2. Rule of Law Index Factors

Constraints on Government Powers	Measures the extent to which those who govern are bound by law. It comprises the means, both constitutional and institutional, by which the powers of the government and its officials and agents are limited and held accountable under the law. It also includes non-governmental checks on the government's power, such as a free and independent press.
Absence of Corruption	Measures the absence of corruption in a number of government agencies. The factor considers three forms of corruption: bribery, improper influence by public or private interests, and misappropriation of public funds or other resources.
Open Government	Measures open government defined as a government that shares information, empowers people with tools to hold the government accountable, and fosters citizen participation in public policy deliberations.
Fundamental Rights	Measures the protection of fundamental human rights. It recognizes that a system of positive law that fails to respect core human rights established under international law is at best "rule by law," and does not deserve to be called a rule of law system.
Order and Security	Measures how well the society assures the security of persons and property. Security is one of the defining aspects of any rule of law society and a fundamental function of the state.
Regulatory Enforcement	Measures the extent to which regulations are fairly and effectively implemented and enforced.
Civil Justice	Measures whether ordinary people can resolve their grievances peacefully and effectively through the civil justice system.
Criminal Justice	Evaluates the criminal justice system. An effective criminal justice system is a key aspect of the rule of law, as it constitutes the conventional mechanism to redress grievances and bring action against individuals for offenses against society.

Adapted from World Justice Project, 2016.

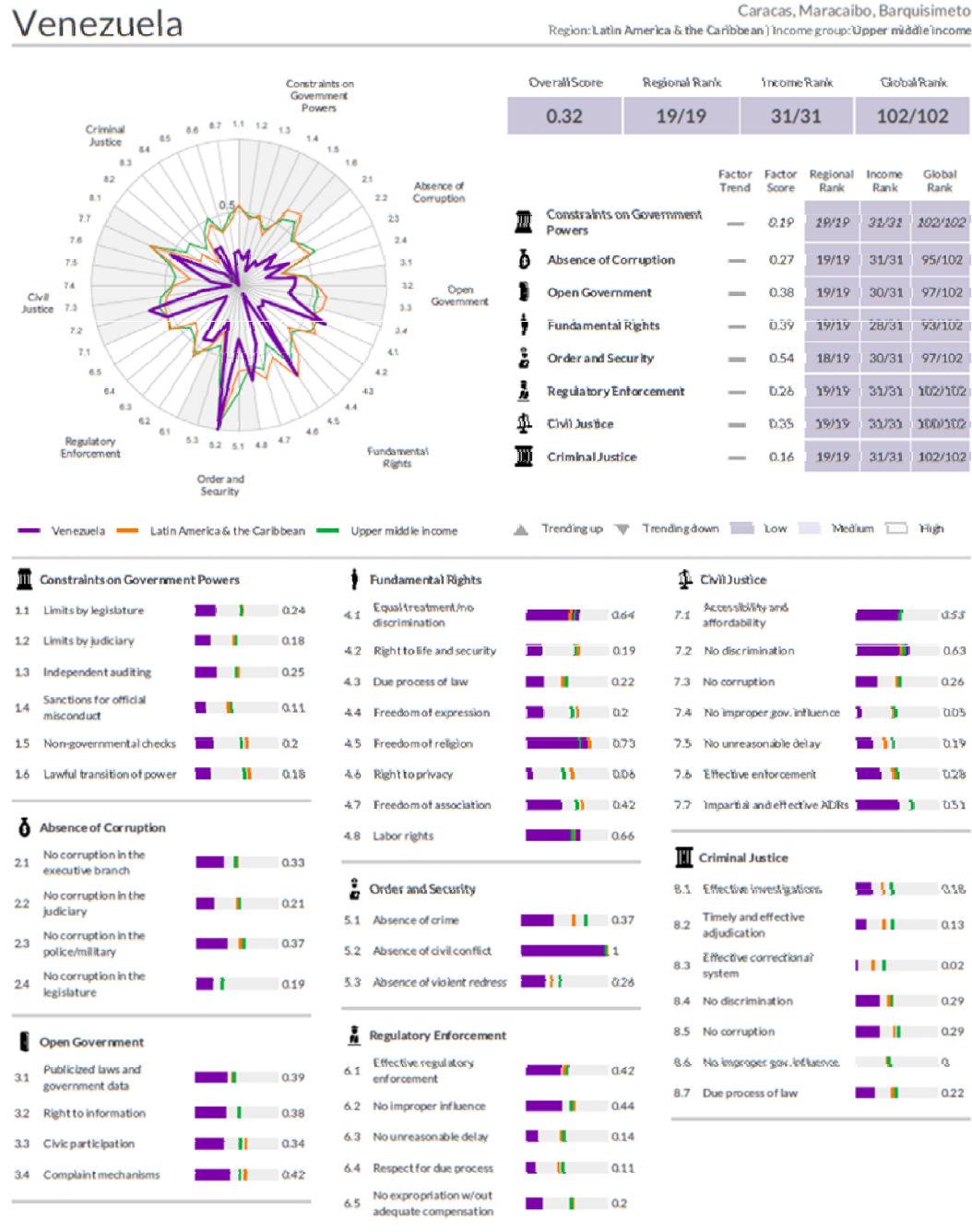


Figure 4. Rule of Law Index for Uruguay



Source: World Justice Project, 2015a. The Rule of Law Index for Uruguay shows positive indicators that it would be a favorable government to work with in a HA/DR environment.

Figure 5. Rule of Law Index for Venezuela



Country profile available at: <http://data.worldjusticeproject.org/#index/VEN>

WJP Rule of Law Index® 2015

Source: World Justice Project 2, 2015b. The Rule of Law Index for Venezuela shows negative indicators that it would not be a favorable government to work with in a HA/DR environment.

## **2. Influence on Government**

China is growing its influence on Latin America. As China's economy continues to grow, so does its appetite for raw, natural resources. It has increased its trade volume between Latin American countries from \$12 billion in 2000 to \$289 billion in 2013 (Watson, 2015). On the surface this is a good thing for Latin America. The increased trade gives much needed money to the region which allows the economy to grow. In addition China also stays out of local politics in that they provide aide and make business deals without conditions on leaders to change bad practices. China does not send political ambassadors to influence policy; rather it gives support via media in an effort to influence business deals. This is detrimental as it inherently does not fix any problems. A government that oppresses its people or at least exploits the poor will still continue to do so. With more money and power given to them, that government has an incentive to reduce its trade and partnerships with the United States because China does not interfere.

China is also notorious for ignoring environment regulations. As part of trade agreements, Chinese companies operate without regard to the damage they cause to the environment. Rain forests are destroyed in search for oil and once the oil is found, precautions are not taken to ensure chemicals and other pollutants are not leaked into the ground, rivers, streams, and lakes (Soutar, 2015). This further exploits the poorer citizens in the region as they do not have a choice but to use the polluted water for their needs as they cannot afford or do not have access to clean potable water (Ray, Gallagher, Lopez, & Sanborn, 2015).

## **B. POPULATION SIZE AND MAKEUP**

The size and makeup of the serving population is important when determining the intended use of the OP and understanding the OP's capacities is imperative to maximize its effective use. Populations too little can render an OP project ineffective as the amount of sewage or trash needed to fuel the OP may

not be enough for it to run. Therefore, the water, electricity, and ash output would not be enough to support the population. Likewise, a large population can supply enough sewage or trash for the OP to run, however, the water, electricity, and ash output could only subsidize that population's requirement.

## 1. Water

The WHO has guidelines on identifying how much water is needed for certain types of use. The amount of water needed varies with climate, the overall health of the people affected, and usage needs. In addition, poor citizens tend to use less water than wealthier citizens as their expectations for water needs are less than that of the wealthy (Reed & Reed, 2011). Water requirements for survival range between 7.5 and 15 liters (1.98 and 3.96 gallons) per day (see Table 3). Minimum emergency water requirements for non-domestic use range from five to 400 liters (1.32 to 105.67 gallons) per day and water quality does not have to be the same for all uses (see Table 4).

Table 3. Simplified Table of Water Requirements for Survival (Per Person)

Type of need	Quantity	Comments
Survival (drinking and food)	2.5 to 3 lpd	Depends on climate and individual physiology
Basic hygiene practices	2 to 6 lpd	Depends on social and cultural norms
Basic cooking needs	3 to 6 lpd	Depends on food type, social and cultural norms
<b>Total</b>	<b>7.5 to 15 lpd</b>	lpd: Litres per day

Source: Reed and Reed, 2011.

**Table 4. Guidelines for Minimum Emergency Water Quantities for Non-Domestic Use**

<b>Use</b>	<b>Guideline quantity</b>
Health centres and hospitals	5 litres/out-patient; 40-60 litres/in-patient/day. Additional quantities may be needed for laundry equipment, flushing toilets, etc.
Cholera centres	60 litres/patient/day; 15 litres/carer/day
Therapeutic feeding centres	30 litres/in-patient/day; 15 litres/carer/day
Operating theatre/maternity	100 litres / intervention
SARS isolation	100 litres / isolation
Viral Haemorrhagic Fever isolation	300-400 litres / isolation
Schools	3 litres/pupil/day for drinking and hand washing (use for toilets not included: see below)
Mosques	2-5 litres/person/day for washing and drinking
Public toilets	1-2 litres/user/day for hand washing; 2-8 litres/cubicle/day for toilet cleaning
All flushing toilets	20-40 litres/user/day for conventional flushing toilets connected to a sewer; 3-5 litres/user/day for pour-flush toilets
Livestock/day	Cattle, horses, mules: 20-30 litres per head; goats, sheep, pigs: 10-20 litres per head, Chickens: 10-20 litres per 100
Vegetable gardens	3-6 litres per square metre per day

Source: Reed and Reed, 2011.

The S100 OP has a capacity of producing 10,800 liters (2,853 gallons) of water per day and can serve up to 1,440 people per day based on a minimal survival need of 7.5 liters (1.98 gallons) per day. The S200 OP has a daily capacity output of 86,000 liters (22,718 gallons) per day and can serve up to 11,466 people. All variables from Tables 3 and 4 have to be considered for the actual need of people to be known.

## **2. Power**

As of 2014, the range of electricity consumption in the United States was 42 to 17 kilowatt-hours (kWh) per day with the average residential household using approximately 30 kWh (U.S. Energy Information Administration, 2015). As of 2014, the average electricity consumption of households per capita in Latin America was 567 kWh annually. The average electricity consumption of electrified households in Latin America was 2053 kWh annually (World Energy Council, 2016). The S100 OP has a maximum capacity of producing 150 kW. Based on a range of 5.62 kWh and 1.55 kWh (annual usage divided by 365 days) used per household per day in Latin America, the S100 can serve between 26 and 96 households with power per day. The S200 OP has a capacity of 250 kW per day and can serve between 44 and 161 households per day.

## **3. Sanitation**

Raw sewage contains many pathogens that are harmful and is composed of about 80% water and 20% biomass (Janicki Bioenergy, 2015). While the S100 OP can only use sewage sludge as fuel, the S200 OP can process sewage sludge and biomass. It is estimated that the average person produces one ounce of feces per pound of body weight (Goodman, 2004). Assuming two liters (.52 gallons) of water intake per day a person can produce 800 to 2000 milliliters (ml) (27.05 to 67.63 fluid ounces) of urine per day (Martin, 2016). The average person generates 1.95 kilograms (4.3 pounds) of trash per day (Duke University Center for Sustainability and Commerce, 2016). There are many variables that determine the output of sewage sludge and biomass and household waste, therefore a careful study of the local population is needed to determine how many people it would take to provide the required sewage sludge and biomass needed to operate the S100 and S200 OP.

## **C. AREA CHARACTERISTICS**

When considering where to place the OP, polluted lakes and rivers and trash dumps should be taken into account. If the population size cannot produce

enough sewage sludge or biomass needed to operate the OP, then the polluted water and trash can be used to subsidize the operating and output requirement of the OP. Utilizing these two negative attributes as sources of fuel and fresh water output will have a significant positive effect on the local environment. As the trash is removed or redirected to use as a fuel source for the OP, the contamination impact on rivers and lakes is reduced.

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## **V. RECOMMENDATION AND CONCLUSION**

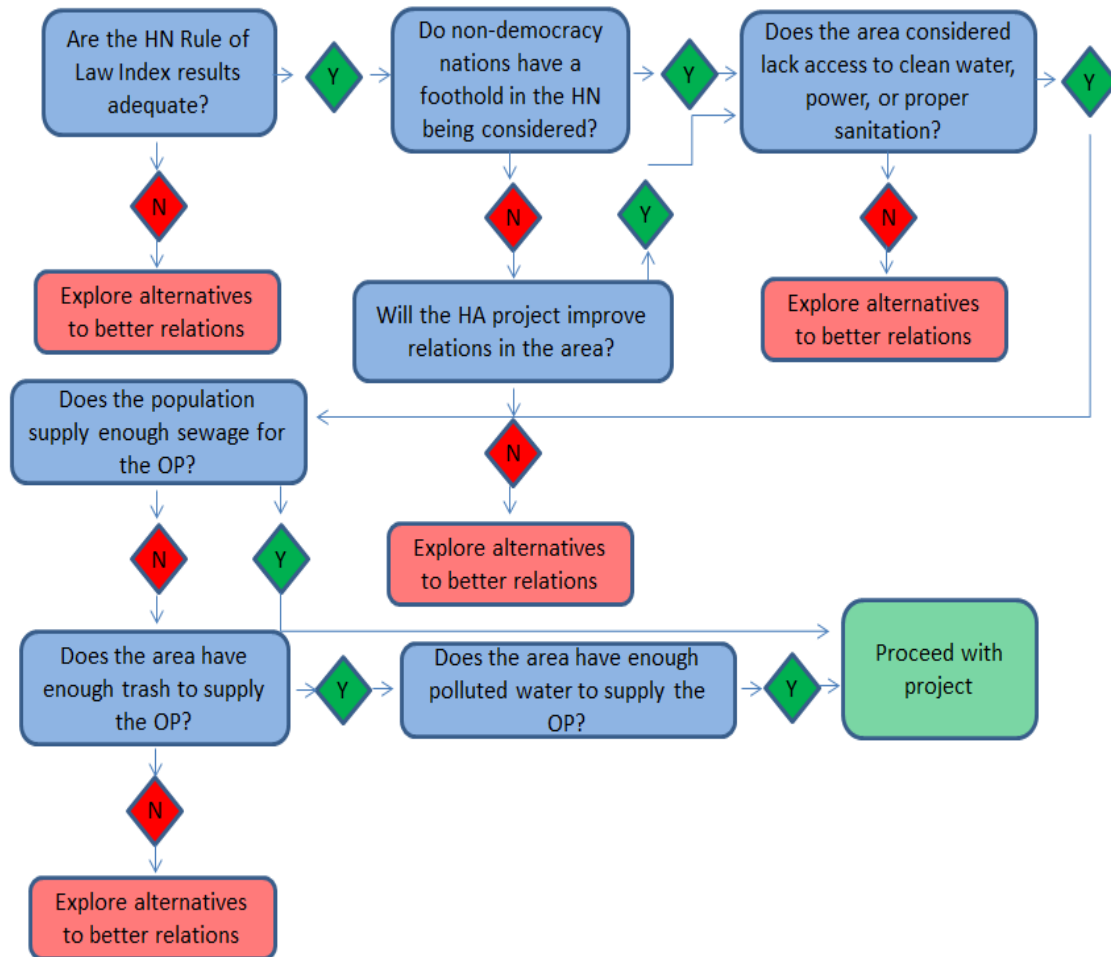
Drinking water is life, but sanitation is dignity.

—Dr. Mbaye Mbeguere, Program Coordinator  
National Institute of Sanitation, Dakar, Senegal

### **A. RECOMMENDATION**

The DSCA could increase its impact on public health and quality of life in Latin America by partnering with USAID and non-government organizations to establish the OP in strategic locations. The OP should be used in a HA capacity or after stage two of DR. To best select locations suitable for the OP, leaders should follow a decision tree (see Figure 6). Scouting locations can be conducted by civil affairs teams trained in proper information gathering and capability assessments of the local environment, civilians and government. These Civil affairs teams have functional expertise in public health, education, and civic planning. The Seabees can conduct the construction requirements required prior to the arrival of the OP to include pouring of a concrete slab, a drainage system, and a conduit for electrical purposes. In addition, the Seabees can use this as an opportunity to train locals on construction techniques, further building the relationship between the United States and the population. Meanwhile, civil affairs teams can work with the local government to recommend rules and policies that benefit all. They can negotiate and make arrangements to ensure that the local government does not hoard the resources and allows its citizens to pay for services via barter and trade in addition to money.

Figure 6. OP Project Decision Tree



## **B. CONCLUSION**

A technology that combines sanitation service, water treatment, and electricity production benefits all people involved in the process. The benefits of a safe water supply and sanitation facility allow for a reduction of water-borne illnesses and other diseases associated with poor sanitation, ultimately reducing deaths and improving the quality of life of the population. With an improvement of health less government money is spent on healthcare, thus that money is redirected toward other beneficial programs.

The United States has long held a position of maintaining good relationships through HA/DR response. The DOD plays a significant role in this because of their capability and resourcefulness. As China's influence on Latin America continues to grow, the United States has a national interest to ensure that China does not create an anti-American sentiment with its neighbors. With access to clean water and proper sanitation a serious problem in Latin America, the United States can use HA/DR as an opportunity for security cooperation in an effort to "improve visibility, access, and influence as well as promote regional stability with Latin American military and civilian counterparts" (DSCA, 2016, p. 12.5.3).

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